AN ASSESSMENT OF THE DRIVERS AND BARRIERS TO BUILDING INFORMATION MODELLING FOR HIGHWAY SCHEMES

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Abstract: *Building Information Modelling (BIM) has often been associated only with Building construction. However, government guidance in Northern Ireland makes no such distinction and includes all Infrastructure and Highways projects over the EU financial threshold. While the drivers and barriers have been ranked for BIM generally in the UK, no such ranking has been undertaken for Highways projects. This paper fills that knowledge gap through a questionnaire survey of organisations that have been forced to use BIM for infrastructure across the UK. It proved the importance of a mandate to implement BIM to achieve the benefits, and highlighted the importance of improving Education and Training in a wholistic approach in overcoming the barriers. It further suggested rebranding BIM as HIM (Highways Information Modelling) to clarify the misconception around its contents*.

Key words: *Highways, Building Information Modelling, Infrastructure, Government Policy*

1. INTRODUCTION

Building Information Modelling (BIM) in the architecture, engineering and construction (AEC) industry has been defined by Borrmann et al. (2020) [1] as "*moving from 2D drawings to digital building models that do not only represent 3D geometry of the building components, but also all the non-geometric data required throughout the building's lifecycle"*. However, it can be seen from this definition that BIM concentrates on the construction and building works aspect of BIM (Vertical BIM) rather than the wider Highways aspect (Horizontal BIM). Within the United Kingdom (UK), when BIM was first mandated by the Efficiency and Reform Group (2011), BIM strategy indicated that the UK Government was making Level 2 BIM mandatory for all publicly-funded projects from 2016 onwards, this did not differentiate between the types of project. Therefore, it applied to horizontal BIM Highway schemes as well as ordinary vertical BIM construction projects.

BIM has been endorsed by the UK Government as a way of increasing collaboration and decreasing fragmentation within construction used in its widest sense (Efficiency and Reform Group, 2011) [2]. Eadie et al (2013) [3] and Eadie et al (2014) [4] examined the drivers and barriers to BIM adoption in the UK generally. However, Wajhi et al. (2019) [8] suggest that the barriers perform differently for Infrastructure Projects. So while the overall drivers and barriers were identified by Eadie et al (2013) [3] and Eadie et al (2014) [4] see Table 1, they had never previously been examined from a Highways perspective. Therefore, the drivers and barriers have been examined from an Infrastructure and Highways perspective in this paper. This examination is the first to rank drivers and barriers to Highway projects in the United Kingdom.

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Some further drivers and barriers were identified in literature after the Eadie et al (2013) [3] and Eadie et al (2014) [4] studies and some were combined. On the driver side, Sanchez et al, (2016) [5], combined two drivers, *Improve Communication to Operatives* and *construction sequencing*, under the more commonly used term *Visualisation* which was used in this study. Barnes and Davies (2015) [6] added *Whole Life Costing Benefits* to the *Whole Life Innovation* in Eadie et al (2013) [3] and these elements were combined in this study. Noor, (2018) [7] identified *Automation of Schedules*, NBS (2018) [8] identified *Pre-fabrication benefits* and *Asset Management Benefits*. These were combined under the *Innovation Process & Fabrication* driver identified by Eadie et al (2013) [3]. NBS (2018) [8] further identified *non-technical people benefits* which was added as a separate driver. As clash detection needs additional software for Level 2 it was only ranked for Level 3. In relation to the barriers, NBS (2018) [8] identified three addition barriers, namely: *Lack of Client Demand/Suitability, Long Learning curves / Implementation time* and the perception that *Only Large companies use BIM*, this latter one was combined with the Eadie et al. (2014) [4] *barrier Lack of Supply chain Buy-in*. Wordnik (2019) [15] combines the two Eadie et al. (2014) [4] barriers *Scale of Culture Change Required* and *Lack of Flexibility* into *Impact on Workplace Culture*, which was used in this study. Table 1 provides a full list of the Drivers and Barriers to BIM.

Table 1: Drivers and Barriers for Building Information Modelling

	Drivers for BIM Adoption	
1	Clash Detection	Eadie et al. (2013)
2	Visualisation - Improve Communication to Operatives and construction sequencing	Eadie et al. (2013), Sanchez et al, (2016)
3	Government Pressure	Eadie et al. (2013)
4	Competitive Pressure or Ambition	Eadie et al. (2013)
5	Cost Savings through Reduced Re-work	Eadie et al. (2013)
6	Whole Life Costing Benefits	Eadie et al (2013), Barnes & Davies (2015)
7	Time Savings / Reduction	Eadie et al. (2013)
8	Cost Savings / Value to Client	Eadie et al. (2013)
9	Client Pressure	Eadie et al. (2013)
10	Health and Safety improvements	Eadie et al. (2013)
11	Innovation Process & Fabrication including Automation of Schedules / Prefabrication & Asset Management benefits	Eadie et al. (2013), Noor, (2018), NBS (2018)
12	Construction Quality Enhancements / Improve Built Output Quality	Eadie et al. (2013)
13	People Benefits	NBS (2018)
	Barriers to BIM Adoption	
1	Cost of Software / Technology / Training	Eadie et al. (2014)
2	Staff Resistance to change / Lack of Senior Management Support	Eadie et al. (2014)
3	Lack of Skilled Staff / ICT Literacy of Staff/Lack of Technical Expertise	Eadie et al. (2014)
4	Legal Uncertainties / Issues	Eadie et al. (2014)
5	Lack of Client Demand	NBS (2018)
6	Impact on Sociotechnical Culture / Scale of Culture Change Required / Lack of Flexibility	Eadie et al. (2014), Wordnik (2019)
7	Software Interoperability Issues	Eadie et al. (2014)
8	Doubts about ROI/Lack of Vision of Benefits	Eadie et al. (2014)
9	Other Competing Initiatives	Eadie et al. (2014)
10	Long Learning curves / Implementation time	NBS (2018)
11	Only Large companies use BIM / Lack of Supply Chain Buy-in	Eadie et al. (2014), NBS (2018)
12	Suitability for current Projects	NBS (2018)

The Efficiency and Reform Group (2011) [2], BIM strategy for the UK made Level 2 BIM mandatory for all publicly funded projects from 2016. Level 2 is defined as a "*Managed 3D environment held in separate discipline "BIM" tools with attached data.* Level 3 has been split into *3A: Enabling improvements in the Level 2 model, 3B: Enabling new technologies and systems.,3C: Enabling the development of new business models. and 3D: Capitalising on world leadership*, by the Digital Built Britain Document (Gov.uk, 2017) [9] and is a process due to be enforced in *the market in mid-2020s*. This continuing process is a strategy to further collaboration and reduce fragmentation in the construction industry identified in Government reports (Wolstenholme et al, 2009 [10]; Egan, 1998 [11]; Latham, 1994[12]). The drivers and barriers identified were previously used to inform the group commenting on the production of the Procurement Guidance Note 03/15 for Northern Ireland (NI) subsequently amended in 2019 (Department of Finance, 2019) [13]. This sets out the requirements for BIM for public sector projects in NI. Without knowing the importance of what is driving BIM forward and what is holding it back it is not possible to fully understand the dynamics behind the implementation. This paper seeks to do this for Level 2 and Level 3 highway projects for the first time.

2. METHOD

Data collection was carried out using LimeSurvey™. This is a software package with connection to a MYSQL database for data collection from the on-line questionnaires. The sample population for the study was 32 organisations who have been selected for highway consultancy frameworks within their retrospective regions (Northern Ireland, England, Scotland and Wales). The questionnaire targeted two samples from each company: a graduate highway engineer and management equivalent. As previously mentioned, these organisations are required to deliver BIM on these projects as they are above the EU procurement threshold. As they are required to implement BIM under the terms of the contract, they are ideal candidates for the research.

The total number of companies initially approached via telephone was the total population of 32 where the telephone operator was asked whether a graduate highway engineer and senior equivalent could participate within the research study (64 total population). Out of the 32 companies, one company was ruled out from the offset as they had no offices within the framework region. From the remaining 31 companies contacted, 15 companies refused to allow contact to an engineer or advised that a general enquiry email was filled out so that it could be completed outside company time.

From the 15 companies who refused contact, their employees were approached via LinkedIn – a social networking website for industry professionals. This brought the sample size to 46, following 6 company refusals and a further 10 questionnaires could not be distributed as no suitable candidate was found or willing to take part in research. This meant that 72% of the total population was surveyed – deemed very good for research by Rubin and Babbie (2009) [14].

In total, 46 online questionnaires invitations were sent out, with 41 full responses and three partial responses which were subsequently discarded. This achieved a response rate of 89%. For a sample size of 46, Isaac and Michael, (1981) recommend a sample size of 40. Therefore, this study achieved the recommended sample size required to validate this study. Four responses had implemented BIM to Level 0 or 1, 27 responses had implemented Level 2 and 10 responses had implemented Level 3 BIM.

In order to produce a further article beyond the scope of this paper a similar method to that of Eadie et al (2013) [3] and Eadie et al (2014) [4] was adopted. This ranked the Highways BIM drivers and barriers using the Relative Importance Index (RII) method to determine the importance of the respondent's ranking on each of the factors. RII is defined by the formulae in equation (1) following:-

(1) $$Relative\ Importance\ Index(RII) = \frac{\sum W}{A\ x\ N}\ (0 \leq index\ \leq 1)$$

Where:

W is the weighting given to each element by the respondents. This will be between 1 and 5, where 1 is the least significant impact and 5 is the most significant impact;
A is the highest weight; and
N is the total number of respondents.

When the RII was determined there were some barriers which scored identically. In order to differentiate between the factors in terms of rank, consideration of the level of rank: the number of respondents scoring 4 or more, and those scoring 3 were noted.

A comparison was carried out between those who had implemented BIM practices to Level 3 and those who had only implemented as far as Level 2 was carried out using the Rank Agreement Factor (RAF).

RAF is defined by the following formulae in equation (2) below:-

(2) $$RAF = \frac{1}{N}\left[\sum_{i=1}^{N} \left|R_{i,1} - R_{i,2}\right|\right]$$

The maximum RAF (RAF_{max}) is calculated as shown in equation (3) below:

(3) $$RAF_{max} = \frac{1}{N}\left[\sum_{i=1}^{N} \left|R_{i,1} - R_{j,2}\right|\right]$$

Where;

$R_{i,1}$ is the rank of item i in group 1,
$R_{i,2}$, is the rank of item i in group 2,
N is total number of items, which is the same for each group,
$R_{j,2}$ is the rank of item j in group 2, and;
$j = N - i + 1$.

Percentage Disagreement (PD) between the two groups is the ratio RAF to RAF_{max}, and it can be determined using the equation shown in equation (4) below:

(4) $$PD = \frac{RAF}{RAF_{max}} \times 100$$

The Percentage Agreement between the rank orders obtained from the two groups can then be calculated as shown in equation 5 below:

(5) $$PA = 100 - PD$$

A higher PD value shows that the agreement between the two groups is weaker. A PD value of zero indicates a complete agreement. To provide further elucidation the barriers were then plotted on a spider diagram.

3. FINDINGS

3.1 Ranked BIM Drivers Results

BIM Drivers results were indicated in Table 2. Where an exact number of responses scored 3 (N=3) and four or more (N ≥ 4) then the barrier was ranked equal. Rank for Level 2, Level 3 and Combined in Table 2 (Rank = RK).

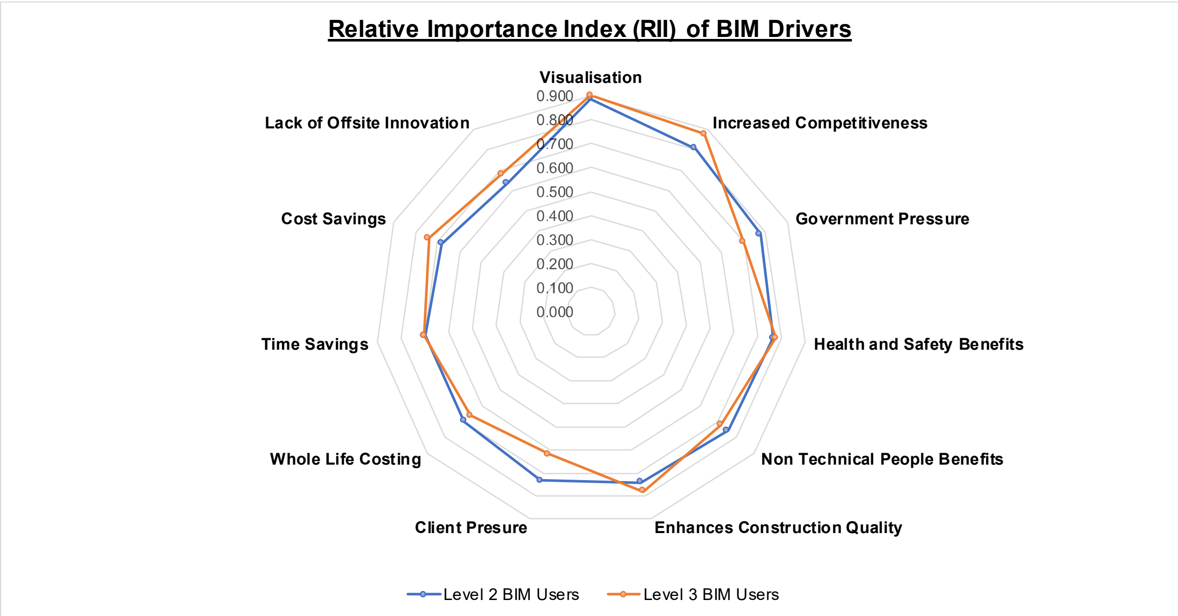
Table 2: Ranked BIM Drivers within the Highways Industry

Drivers	Level 2 BIM Users					Level 3 BIM Users						Combined	
	Mean	N≥4	Sum	RII	Rk	Mean	N=3	N≥4	Sum	RII	Rk	RII	Rk
Clash Detection						4.40	2	8	44	0.880	2^	0.880	2
Visualisation	4.44		120	0.889	1	4.50			45	0.900	1	0.892	1
Competitive Pressure	4.04		109	0.807	2	4.40	2	8	44	0.880	2^	0.827	3
Government Pressure	3.89		105	0.778	3	3.50		6	35	0.700	8*	0.757	5
Health and Safety Benefits	3.85		104	0.770	4	3.90	3	7	39	0.780	4#	0.773	4
People Benefits	3.78		102	0.756	5	3.60			36	0.720	7	0.746	7
Enhances Construction Quality	3.70		100	0.741	6	3.90	2	7	39	0.780	5#	0.751	6
Client Pressure	3.67		99	0.733	7	3.10			31	0.620	12	0.703	8
Whole Life Costing	3.48	16	94	0.696	8*	3.30			33	0.660	11	0.686	11
Time Savings	3.48	14	94	0.696	9*	3.50		5	35	0.700	8*	0.697	10*
Cost Savings	3.41		92	0.681	10	3.70			37	0.740	6	0.697	9*
Innovation Process & Fabrication	3.19		86	0.637	11	3.40			34	0.680	10	0.649	12
Total	40.93					45.20							
Total Mean Score	3.721					3.767							
* = Ranked after ≥ 4 Analysis ^ = Joint ranking after = 3 Analysis # = Ranked after = 3 Analysis													

From the results in Table 2, overall the two user groups mean score indicates that the drivers to BIM are of equal importance: Level 2 BIM users (mean score 3.72) and Level 3 BIM users (mean score 3.77). The closer the Relative Importance Index (RII) Value gets to 1, the more important the driver. *Clash Detection* was indicated as a driver for those respondents who have only adopted BIM to Level 2 because it is a driver that is not associated with the UK Governments Level 2 Compliance and not managed within a federated model. (NBS, 2017 [17]).

For Level 2 BIM Users the top 3 drivers are; *Visualisation, Competitive Pressure* and *Government Pressure*. For Level 3 BIM Users they are; *Competitive Pressure, Visualisation* and *Clash Detection*. This highlights the importance of the embedded clash detection. The importance of Government Pressure is seen in that the 2016 deadline ensured it was ranked 3rd for Level 2 but the mid 2020's deadline for Level 3 means it is only in 8th position. The least important three drivers for Level 2 are; *Time Savings, Cost Savings* and *Innovation*. Furthermore, those who are working to Level 3 BIM, the three least important drivers are; *Innovation Process and fabrication; Whole Life Costing* and *Client Pressure*. The importance of clients asking for Level 3 instead of Level 2 is highlighted in this ranking. Overall the top three most important drivers within the highways industry are; *Visualisation, Clash Detection* and *Increased Competitiveness*. The three least important drivers in terms of relative importance in the highways industry are *Time Savings, Whole Life Costing* and *Innovation*. The importance of each of the drivers are shown in Figure 1. *Clash detection* is not compared as it was not part of Level 2.

Figure 1: BIM Drivers within the Highways Industry



These results indicate that for any government document on the implementation of BIM within the highways industry should mention *Clash Detection* and *Visualisation*.

Table 3 shows that the RAF between Level 2 and Level 3 BIM Users on the drivers to BIM in the highways industry is 2 and a RAFmax of 5.09, PD is 39.396% and PA of 60.71%. Therefore, there is a difference in ranking depending on the level of implemented BIM Maturity. Table 3 indicates the driver with the largest variance between Level 2 and 3 is *Client Pressure*. Therefore clients are requesting Level 2 but much less Level 3.

Table 3: RAF, PD and PA values for BIM Drivers within the Highways Industry

Drivers	L2 RK	L3 RK	Ri1-Ri2	AV	J	Ri1-Rj2	Absolute Value
Clash Detection							
Visualisation	1	1	0	0	11	-10	10
Competitive Pressure	2	2	0	0	10	-8	8
Government Pressure	3	7	-4	4	5	-2	2
Health and Safety Benefits	4	3	1	1	9	-5	5
People Benefits	5	6	-1	1	6	-1	1
Enhances Construction Quality	6	4	2	2	8	-2	2
Client Pressure	7	11	-4	4	1	6	6
Whole Life Costing	8	10	-2	2	2	6	6
Time Savings	9	8	1	1	4	5	5
Cost Savings	10	5	5	5	7	3	3
Innovation Process & Fabrication	11	9	2	2	3	8	8
			AV Sum	22		AV Sum	56
			RAF	2		RAFmax	5.090909091
			PD	39.29		PA	60.71428571

3.2 Ranked BIM Barriers Results

BIM Barrier results were indicated in Table 4. Similar to the drivers, where an exact number of responses scored 3 (N=3) and four or more (N ≥ 4) then the barrier was ranked equal. Rank for Level 2, Level 3 and Combined in Table 2 (Rank = RK).

Table 4: Ranked BIM Barriers within the Highways Industry

Barriers	Level 2 BIM Users					Level 3 BIM Users						Combined	
	Mean	N≥4	Sum	RII	Rk	Mean	N=3	N≥4	Sum	RII	Rk	RII	Rk
Long Learning Curves	3.407		92	0.681	1	4.000			40	0.800	2	0.733	1
Lack of Skilled Personnel	3.259		88	0.652	2	4.100			41	0.820	1	0.717	2
Legal Issues	3.185		86	0.637	3	2.800		1	28	0.560	9*	0.633	3
Only Used in Large Consultancy Firms	2.926		79	0.585	4	3.300	3	5	33	0.660	4^	0.622	5
Costs	2.778	9	75	0.556	5*	2.800		2	28	0.560	8*	0.572	9
Doubts over Return On Investment (ROI)	2.778	8	75	0.556	6*	3.700			37	0.740	3	0.622	4
Competing Initiatives	2.741		74	0.548	7	2.700			27	0.540	10	0.561	10
Software Interoperability Issues	2.704		73	0.541	8	3.300	2	5	33	0.660	7^	0.589	6
Resistance to Change	2.667		72	0.533	9	3.300	3	5	33	0.660	4^	0.583	7
Lack of Client Demand	2.593		70	0.519	10	3.300	3	5	33	0.660	4^	0.572	8
Unsuitable for Current Projects	2.037		55	0.407	11	2.300			23	0.460	11	0.433	11
Impact on work place culture	1.704		46	0.341	12	1.800			18	0.360	12	0.356	12
Total	32.778					37.40							
Total Mean Score	2.731					3.117							
* = Ranked after ≥ 4 Analysis ^ = Joint ranking after = 3 Analysis # = Ranked after = 3 Analysis													

It can be seen from Table 4 that there is a substantial bigger weighting to the barriers to Level 3 than those for Level 2. Level 2 BIM Users (Mean 2.731), differed from Level 3 BIM users (mean 3.117). This suggests that the advancement to BIM Level 3 will be more difficult as the barriers are greater and the demand for Level 3 BIM Users from clients in joint fourth, up from eighth position for Level 2.

The top three barriers overall and for Level 2 BIM Users are; *Long Learning Curves, Lack of Skilled Personnel* and *Legal Issues*. Whereas, the top three barriers for those who are working to Level 3 BIM in the highways sector are; *Long Learning Curves, Lack of Skilled Personnel* and *Doubt over Return on Investment (ROI)*. This indicates that the balance of costs against benefits for Level 3 has yet to come across strongly in industry.

This study found that the three least important barriers for those who are working to Level 2 BIM are; *Lack of Client Demand, Unsuitable for Current Projects* and *Negative effect on workplace culture*. Lessons from these results are that Clients are demanding at least Level 2 BIM currently and that there are options on all types of projects for its use. On the other hand, for those who have implemented Level 3 BIM and overall, the three least important barriers are; *Other competing initiatives are more important, Unsuitable for Current Projects* and *Negative effect on workplace culture*. Again these results emphasise that Government demands through other competing initiatives and a mid 2020's target reduce the need to progress with Level 3 BIM. Figure 2 demonstrates the barrier results graphically.

Figure 2: BIM Barriers within the Highways Industry

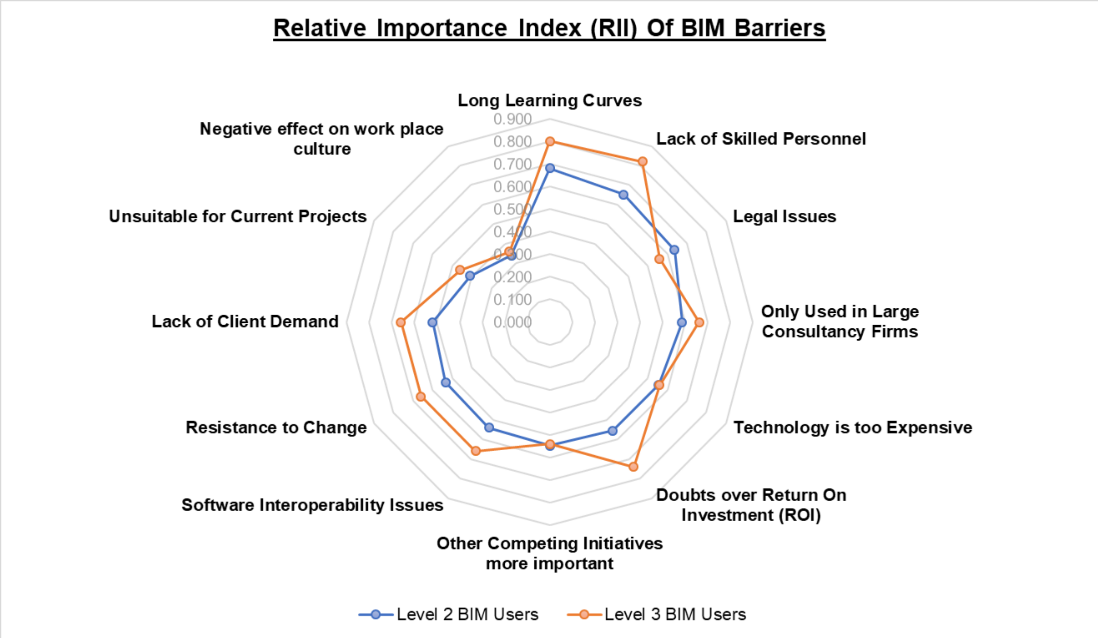


Table 5 indicates that the RAF between Level 2 and Level 3 Users on the barriers to BIM in the highways industry is 2 and a RAFmax of 4.5, producing a PD of 53.70% and a PA of 46.30%.

Table 5: RAF, PD and PA values for BIM Barriers within the Highways Industry

Barrier	L2 RK	L3 RK	Ri1 - Ri2	AV	J	Ri1 - Rj2	AV
Long Learning Curves	1	2	-1	1	12	-11	11
Lack of Skilled Personnel	2	1	1	1	11	-9	9
Legal Issues	3	9	-6	6	4	-1	1
Only Used in Large Consultancy Firms	4	4	0	0	6	-2	2
Costs	5	8	-3	3	5	0	0
Doubts over Return On Investment (ROI)	6	3	3	3	10	-4	4
Competing Initiatives	7	10	-3	3	3	4	4
Software Interoperability Issues	8	7	1	1	8	0	0
Resistance to Change	9	4	5	5	7	2	2
Lack of Client Demand	10	4	6	6	9	1	1
Unsuitable for Current Projects	11	11	0	0	2	9	9
Impact on work place culture	12	12	0	0	1	11	11
			AVSum	29		AVSum	54
			RAF	2.42		RAF MAX	4.5
			PD	53.70		PA	46.30

Some qualitative data provided from the questionnaire responses, suggested BIM be rebranded as HIM – Highways Information Modelling. Though this was caveated with the need for the introduction of interoperable software that involves common templates for the whole industry and yet is exclusive to road/highway engineering. The future promotion of BIM as HIM would result in clarity in relation to Highways and remove the ambiguity currently linking BIM with just buildings and structures.

4.0 DISCUSSION AND CONCLUSIONS

A clear message from the results of the survey is the importance of a mandate to implement BIM. Eadie et al (2015) [16] showed that the impact of Government pressure to adopt BIM. Furthermore, the importance of improving education and training alongside government guidance will provide a wholistic approach. The top two barriers of this study; *long learning curves* and *lack of skilled personnel* could be overcome with this improved education and training. The difference in the ranking of the barriers to BIM for highways Level 2 and 3 proves that *Government Pressure* is really impactful in getting the benefits of BIM implemented. Eadie et al(2013)[16] show savings result throughout the project lifecycle.

If clients are not fully aware of the benefits of BIM, then they are less likely to adopt it on a scheme. As clients specify the Employer's Information Requirements (EIR) adoption of BIM throughout the construction industry, not just in the highways sector, needs to have intelligent clients well trained in what can be achieved through BIM. Production of Employer’s Information Requirements for other countries based on this previous success must be a priority. Currently clients are only meeting the public sector requirement for Level 2. Further work from a government standpoint is required if Level 3 is to be achieved. Therefore, within the infrastructure and highways industry, it is important that the promotion of BIM showcases the potential drivers that include; *increased competitiveness* within the industry, enhanced *visualisation* of projects and the *health and safety benefits* throughout the construction life cycle. When referring to building information modelling, it is a common misperception that the process can only be applied to buildings, structures or mechanical and electrical aspects of a building. However, if no such distinction is made in the government guidance, savings will also be incurred within infrastructure and highways projects.

The rebranding suggested by the qualitative data within the questionnaire, which suggested BIM be rebranded as HIM – Highways Information Modelling through the introduction of interoperable software that involves common templates for the whole industry and is exclusive to road/highway engineering. The future promotion of Building Information Modelling as Highway Information Modelling would lose the ambiguity which currently associates BIM with just buildings and structures and creates a more specific and feasible approach to highway industry.

In conclusion this paper has analysed the drivers and barriers to BIM for the UK highways sector and suggests ways of overcoming the barriers to BIM through two key areas; training and continued government pressure. The success of government pressure in the past can be used as a template for other countries implementation of BIM.

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